Resilient Characteristics of Stone Matrix Asphalt Mixes

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***Abstract*— Stone Matrix Asphalt (SMA) is a gap graded mix, characterized by high coarse aggregates, high asphalt contents and polymer or fiber additives as stabilizers. In comparison to dense graded mixtures SMA has higher proportion of coarse aggregate, lower proportion of middle size aggregate and higher proportion of mineral filler. It resists permanent deformation and has the potential for long term performance and durability. In the present study, an attempt has been made to study the resilient properties of mixtures of stone matrix asphalt made with two types of conventional binders namely bitumen 80/100 and 60/70, with 0.3% by weight of a non – conventional natural fiber, namely coconut fiber. The mixes are subjected to both static and repeated load indirect tensile strength tests. It is observed that the natural fibres have propounding effect on the resilient properties of the mixes**.

***Index Terms*— stone matrix asphalt, coconut fibre, repeated load indirect tensile test**

I. INTRODUCTION

Aggregates bound with bitumen are conventionally used all over the world in construction and maintenance of flexible pavements. The close, well, uniform, or dense graded aggregates bound with normal bitumen normally perform well in heavily trafficked roads if designed and executed properly and hence very common in paving industry. However, it is not always possible to arrange dense graded aggregates available at the site, In such situations a bituminous mix called stone matrix asphalt (SMA) which basically is a gap graded mixture containing 70-80% coarse aggregate of total aggregate mass, 6-7% of binder, 8-12% of filler, and about 0.3-0.5% of fibre or modifier. The stabilizing additives composed of cellulose fibers, mineral fibers, or polymers are added to SMA mixtures to prevent draindown from the mix. The high amount of coarse aggregate in the mixture forms a skeleton-type structure providing a better stone-on-stone contact between the coarse aggregate particles, which offers high resistance to rutting. The higher binder content makes the mix durable. The fibres or modifier hold the binder in the mixture at high temperature; prevent drainage during production, transportation and laying. Brown and Mallick (1994), Mogawer and Stuart (1996), Putman et al. (2004), and Neubaur and Partl (2004) have used unmodified binders for study of SMA mixes. Mostly cellulose fibres have been tried by various investigators in SMA mixes to solve the draindown problem. These fibres are either costly or not readily available. As reported by Khalil et al (2006) coconut fibre contains certain amount of cellulose. Considering this, Suchismita (2009) observed that, commonly used binders such as 80/100 and 60/70 penetration grade bitumen can be used with locally available coarse aggregates with 0.3% coconut fibres by weight. An attempt has been made in this study to utilize a naturally and abundantly available low cost material such as locally available coconut fibre, in preparation of SMA mixes and study the resilient properties of the SMA mixes.

II. EXPERIMENTAL PROGRAMS

A. Materials Used

For preparation of SMA mixes, aggregates with aggregate grading adopted by National Council for Highway Research Program (NCHRP) of Transportation Research Board (TRB), USA has been adopted. Coarse aggregates up to 4.75 mm IS sieve size, consisted of stone chips collected from a local source. Fine aggregates, consisting of stone crusher dusts were collected from a local crusher with fractions passing 4.75 mm and retained on 0.075 mm IS sieve. Portland slag cement (Grade 43) collected from local market passing 0.075 mm IS sieve was used as filler material. Conventional penetration grade bitumen 80/100 and 60/70, collected from a local depot was used in preparation of mix samples. Coconut fibre/ coir fibre is a natural fibre derived from the mesocarp tissue or husk of the coconut fruit. It is also termed as 'Golden Fibre' due to its color. The individual coconut fibre cells are narrow and hollow, with thick walls made up of cellulose. These fibres are pale when immature but later they become hardened and yellowed as a layer of lignin gets deposited on it. Brown coir fibres are stronger as they contain more lignin than cellulose, but they are less flexible. Coconut fibres are made up of small threads and are relatively water proof. The peelings of ripe coconut were collected locally, dried and neat fibres taken out manually. The lengths of such fibres were normally in the range of 75 to 200 mm and diameter varied from 0.2 to 0.6 mm. The tensile strength of these fibres was tested in a materials testing machine, Tinious Olsen, UK, Model HIOKS. The average tensile strength of the fibre was found to be 70.58 N/mm^2.

B. Preparation of Mixes

As reported by Suchimita (2009) the mixture of coarse aggregates, fine aggregates and cement are heated to the required temperature. Coconut fibres after being cut to small pieces approximately 3-5 mm long, (0.3%) by weight are added directly to aggregate sample and thoroughly mixed before adding required quantity of binder. The mixes are thoroughly mixed and prepared as per the normal Marshall procedure.

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C. Tests on Mixes

Indirect tensile test

In this test, a compressive load is applied on a cylindrical specimen (Marshall Sample) along a vertical diametrical plane through two curved loading strips13 mm (1/2″) wide, 13 mm deep and 75 mm long having inside diameter same as that of a Marshall sample (102 mm). The static indirect tensile strength of a given specimen is determined using the procedure outlined in ASTM D 6931 (2007) at temperatures varying from 5ÚC to 40ÚC at an increment of 5ÚC. A loading rate of 51 mm/minute is adopted. The load is applied and the failure load noted from the dial gauge of the proving ring. The tensile strength of the specimen is calculated by using the given formula.

D. Repeated Load Indirect Tensile Test

The repeated load indirect tensile test was conducted in a set up designed and fabricated in the Highway Engineering Laboratory of N.I.T., Rourkela as shown in Fig. 1. This test is similar to the static indirect

Fig. 1 Repeated load indirect tensile test setup

tensile test in principle where instead of static load a repeated load is applied with a suitable frequency, having appropriate loading time and rest period. Both horizontal and vertical deformations are accurately measured. The resilient modulus of elasticity, resilient Poisson's ratio, tensile stress, tensile strain etc. is computed by using the equations suggested by Kennedy (1978). Fatigue life is the number of load applications to cause failure at a particular stress level for a mix at a particular temperature. Fatigue life was noted directly from the output of the computer software.

III. ANALYSIS OF RESULTS AND DISCUSSIONS

A. Static Indirect Tensile Test

It is seen that the fibre addition results higher tensile strength. It is also observed that for a particular binder, the tensile strength decreases with increase in temperature. At lower temperature, the mixes with 60/70 bitumen has the higher indirect tensile strength than 80/100 bitumen. But at higher temperatures, the mixes with 60/70 binder have the highest tensile strength as compared to the mixes with other two binders.

B. Repeated Load Indirect Tensile Test

The parameters studied in this test are the resilient Poisson's ratio (μ_R), resilient modulus of elasticity (M_R) and fatigue life (N_f) at varying stress levels and at three most prevailing temperatures, namely 25°C, 30°C and 35°C. Figure 2 shows the variations of resilient modulus of elasticity with tensile stress for different mixes at three different testing temperatures. For mixes without fibre the decrease in M_R value with stress level is more as compared to the mixes with fibre. In case of mixes with and without fibre, at a particular temperature and a particular stress level mixes with 60/70 bitumen have more M_R value than that with 80/100 bitumen.

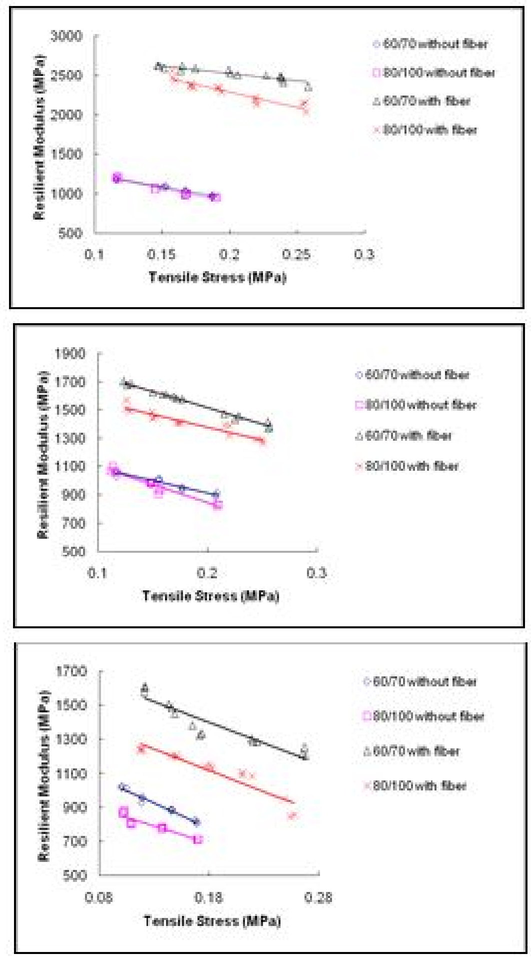

Fig. 2 Variation of Resilient moduli with Tensile stress at different temperatures

C. Relationship between fatigue life (N_f) and stress difference ($\Delta\sigma$)

The variation of fatigue life with stress difference for SMA mixes with the two types of binder at three different temperatures are shown in Figures 4 (i) to (iii) for mixes without fibre. It is observed that addition of fibre to the mix improves its fatigue life. At a particular test temperature and for a particular stress difference value, the mixes with 60/70 binder have the longest fatigue life value as compared mixes with 80/100 binder.

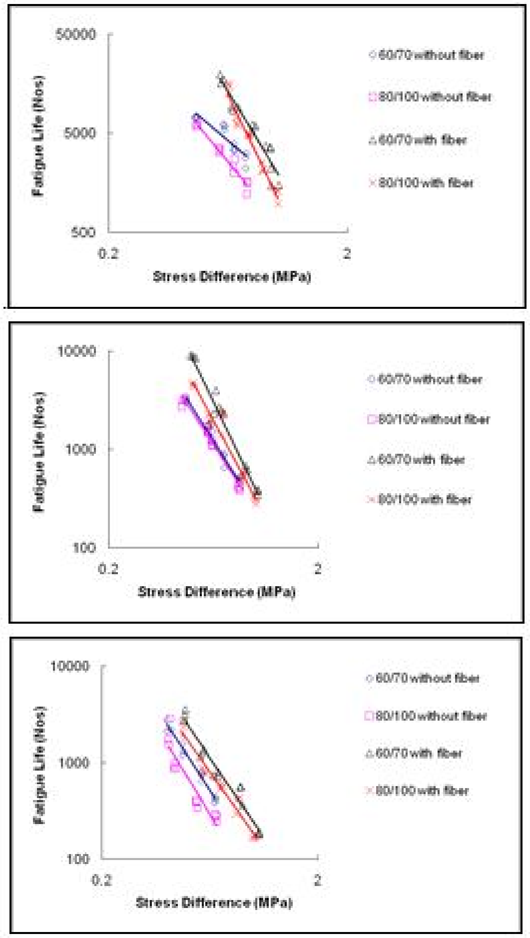

Fig. 4 Variation of fatigue life with stress difference for different mixes

IV. CONCLUSIONS

Coconut fibres have been used in this study as a stabilizing additive in place of conventional cellulose fibres in SMA mixes and the paving mixes have been evaluated in terms of the static and resilient properties. Addition of fibres results in higher tensile strength for a given bitumen sample at a given temperature. The resilient modulus value does not change significantly with applied tensile stress. It is also observed that a mere 0.3% incorporation of binder results in considerable increase of the resilient moduli and fatigue life of the mixes, which is an added advantage to the paving industry.

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